SAT20: Emergent 4D Filament–Surface Theory

Abstract

We present a theoretical framework for the emergence of spacetime geometry, quantum mechanics, and Standard Model gauge structures from minimal geometric and dynamical assumptions. Structures are emergent from a differentiable 4D manifold and a filament ensemble, without manually inserted constants and with explicit falsifiability criteria.

1 Introduction

We develop a 4D action-based physical theory starting from a differentiable manifold M and a set of particle worldlines (filaments), introducing new structures only when logically and physically compelled. No metric, connection, or gauge field is assumed initially. Emergent structures are subject to explicit falsifiability.

2 Fundamental Structures

Manifold: M, a smooth, 4D differentiable manifold.

Worldlines: Filaments are smooth embeddings $\gamma : \mathbb{R} \to M$ with tangent vector $v^\mu = d\gamma^\mu/d\lambda$.

3 Emergent Time Orientation and Foliation

Filament Current:

$$J^\mu(x) = \sum_\gamma \int d\lambda \, v^\mu(\lambda)\delta^4(x - \gamma(\lambda)) \tag{1}$$

Emergent 1-Form: Define $\tau_\mu(x) \propto J_\mu(x)$ dynamically.

Foliation: Construct $\phi(x)$ locally via

$$d\phi(x) = \tau_\mu(x)dx^\mu \tag{2}$$

where integrability is examined through local Frobenius conditions and vorticity in the filament congruence.

4 Filament Vorticity and Integrability

Generic initial filament conditions (random initial orientations) lead to nonzero vorticity $\omega_{\mu\nu}$ in the filament congruence. The evolution of vorticity follows a Raychaudhuri-type equation in the absence of dissipative forces, yielding

$$\frac{d\omega_{\mu\nu}}{d\lambda} \approx 0 \tag{3}$$

thus preserving vorticity along filaments. Nonzero vorticity prevents convergence and supports the construction of an approximately integrable τ and local time foliation ϕ.

5 Emergent Metric and Filament–Surface Dynamics

Emergent Metric:

$$\tilde{g}^{\mu\nu}(x) = \langle v^\mu v^\nu \rangle \tag{4}$$

6 Co-Metric Invertibility from Filament Distribution

Given a dense, random distribution of filament velocities not supported on a lower-dimensional subspace, the probability that at least four filaments at any point have linearly independent velocities is one (almost surely), suggesting that the co-metric $\tilde{g}^{\mu\nu}$ is invertible at almost every point in M. The statistical independence of filament velocities is related to nonzero vorticity and initial conditions.

Filament–Surface Interaction: Coupling determined via projections onto τ_μ and gradients of ϕ.

7 Quantization of Filament Perturbations

Action:

$$S_{\text{filament}} = -T \int d\lambda \sqrt{g_{\mu\nu} v^\mu v^\nu} \tag{5}$$

Perturbations:

$$\xi^\mu(\lambda), \quad v_\mu \xi^\mu = 0 \tag{6}$$

Canonical Momenta:

$$\pi_\mu(\lambda) = T \frac{d\xi_\mu}{d\lambda} \tag{7}$$

Hamiltonian:

$$\mathcal{H} = \frac{1}{2T} \pi^\mu \pi_\mu \tag{8}$$

Quantization:

$$[\hat{\xi}^\mu(\lambda), \hat{\pi}_\nu(\lambda')] = i\delta^\mu_\nu \delta(\lambda - \lambda') \tag{9}$$

8 Emergent General Relativity

Einstein Equations:

$$G_{\mu\nu}[g] = 8\pi G_{\text{eff}} T_{\mu\nu} \tag{10}$$

where

$$G_{\text{eff}} \sim \frac{1}{T} \tag{11}$$

9 Emergent Quantum Mechanics and Standard Model

Hilbert Space: Built from quantized filament vibration modes.

Gauge Groups Suggested:

- U(1) associated with single loop winding number.
- SU(2) associated with linking number symmetry in double filament links.
- SU(3) associated with triple linking (Borromean rings) symmetry structures.

10 Planck Scale from Filament Dynamics

Derived Constants:

$$\ell_p \sim \frac{\ell_f}{c_\phi^2} \tag{12}$$

$$m_p \sim T\ell_f \tag{13}$$

$$\hbar_{\text{eff}} \sim \frac{T\ell_f^2}{c_\phi} \tag{14}$$

where

$$\boxed{\ell_f = \left(\frac{2A}{T}\right)^{1/3}} \tag{15}$$

is proposed to emerge from variational ground state energy minimization under topological constraints.

11 Falsifiability Criteria

- Failure of local foliation (no integrable τ) implies model falsification.
- Degenerate co-metric (filament velocity collapse) implies model falsification.
- Absence of topological configurations leading to gauge group emergence implies model falsification.
- Inconsistencies in Planck constants derived from T and A imply model falsification.

12 Conclusion

The SAT20 emergent filament–surface theory constructs spacetime geometry, quantum mechanics, and Standard Model-like gauge structures from minimal initial assumptions, with structures derived dynamically and explicit falsifiability criteria at each stage.

References

Placeholder for references.